

**TITLE**

**IMAGE SENSOR WITH GUARD RINGS AND METHOD FOR FORMING THE  
SAME**

**BACKGROUND OF THE INVENTION**

**5 Field of the Invention**

This invention relates generally to an image sensor. In particular, it relates to an image sensor with optical guard rings to prevent cross-talk between adjacent pixels.

**Description of the Related Art**

10 Solid state image sensors are necessary components in many optoelectronic devices, including digital cameras, cellular phones, and toys. Conventional solid-state image sensors for color analog or digital video cameras are typically charge-coupled device (CCD) or complementary metal  
15 oxide semiconductor (CMOS) photodiode array structures which comprise a spectrally photosensitive layer below one or more layers patterned in an array of color filters and above which resides a surface-layer array of microlens elements. The elementary unit of the image sensor is defined as a  
20 pixel. The basic technology used to form the CMOS image sensor is common to both types sensors.

The CMOS image sensor comprises a photo detector for detecting light and a logic circuit for converting the detected light into an electric signal representing data  
25 regarding the detected light. The fill factor, sometimes referred to as the aperture efficiency, is the ratio of the size of the light-sensitive area to the size of the total

pixel size. Although efforts have been made to increase the fill factor of the image sensor and thereby increase the sensor sensitivity, further increases in the fill factor are limited because the associated logic circuitry cannot be completely removed. Accordingly, in order to increase the sensitivity of the light, a microlens formation technology has been used to converge and focus the incident light onto the photo detector by changing the path of the light that reaches the lens of the photo detector. In order for the image sensor to detect and provide a color image, it typically must include both a photo detector for receiving the light and generating and accumulating charge carriers and a color filter array (CFA), i.e., a plurality of color filter units sequentially arranged above the photo detector. The CFA typically uses one of two alternative three-color primary configurations, either red R, green G and blue B (RGB) or yellow Y, magenta M and cyan C (CMY). A plurality of microlenses are positioned above the color filter array to increase the photosensitivity of the image sensor.

FIG. 1 shows a traditional image sensor disposed in the substrate. The incident light 30 may not effectively focus on the photodiode 12 and may transmit to the adjacent photodiode 12'. As the pixel size is shrunk and multi-layer metal is used to reduce sensor cost, the cross-talk issue is more serious due to light scattering coming from metal layers 16 and 20. Thus, image resolution is degraded, especially for black and white sensors, and color correction is more difficult for color sensors.

### **SUMMARY OF THE INVENTION**

Accordingly, it is the object of this invention to provide an image sensor to prevent cross-talk from occurring between adjacent pixels.

5        To achieve the above objects, an image sensor with air gaps as optical guard rings is provided. The air gaps are formed in the stacked inter-metal dielectric layer between the sensor areas, and a light transmitting insulating layer is disposed on the stacked inter-metal dielectric layer  
10 without filling the air gaps. Therefore, the incident light cannot transmit to the adjacent pixel.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 shows a traditional image sensor disposed in the substrate.

15        FIGS. 2A to 2C illustrate a method for fabricating an image sensor in accordance with the present invention.

FIG. 3 shows an image sensor with air gaps formed by two or more etching processes and separated by light transmitting insulating layers.

20        FIG. 4 shows an image sensor with air gaps in parts of the whole inter-metal dielectric layers.

FIG. 5 shows the relationship between cross-talk and the incident angle of incident light occurring in the traditional image sensor without optical guard rings in the  
25 stacked inter-metal dielectric layer and the image sensor of the present invention with air gaps formed in the inter-metal dielectric layers as the optical guard rings.

FIG. 6 shows the device designed to measure the cross talk for image sensors with or without air gaps as optical guard rings.

#### **DETAILED DESCRIPTION OF THE INVENTION**

5        FIGS. 2A to 2C illustrate a method for fabricating an image sensor in accordance with the present invention by significantly modifying the conventional image sensor fabrication process using air gaps as optical guard rings.

10        As shown in FIG. 2A, a sensor area, such as a photodiode 102, is formed in a semiconductor substrate 100. Other elements, such as transistors (not shown), are also formed in or on the semiconductor substrate 100. An interlayer dielectric layer (ILD layer) 104, which is a light transmitting pre-metal dielectric layer, is formed on  
15 the semiconductor substrate 100 to cover those elements. A first metal layer is then deposited on the ILD layer 104 and selectively patterned to form a first metal line 106 on the ILD layer 104 except above the photodiode 102. After a first inter-metal dielectric layer 108, for insulating  
20 adjacent metal lines from each other, is deposited and planarized on the first metal line 106, a second metal layer is deposited on the first inter-metal dielectric layer 108 and selectively patterned and etched to generate a second metal line 110 positioned generally above the first metal  
25 line 106. A second inter-metal dielectric layer 112 for insulating the adjacent metal lines 110 from each other is deposited and planarized. The following interconnection process for forming the inter-metal dielectric layers 116 and 120 is then performed. In the figure, inter-metal  
30 dielectric layers 108, 112, 116 and 120 are shown as an

exemplary embodiment. It is understood that more or fewer inter-metal dielectric layers could be used. Inter-metal dielectric layers 108, 112, 116 and 120 are shown as a stacked inter-metal dielectric layer 122 in the following  
5 FIGS. 2B-2C.

As shown in FIG. 2B, an energy sensitive layer, such as photoresist layer 124, is deposited on the stacked inter-metal dielectric layer 122 and patterned utilizing conventional photolithography process to form an optical  
10 guard ring pattern. The patterned photoresist layer 124 with the optical guard ring pattern is used as a mask for etching the stacked inter-metal dielectric layer 122, thereby forming air gaps 126 between pixels, that is, around each pixel boundary.

As shown in FIG. 2C, a light transmitting insulating layer 128 is formed on the stacked inter-metal dielectric layer 122 without filling the air gaps 126. The light transmitting insulating layer 128 is, for example, an oxide layer deposited by PECVD with a thickness of 3,500 - 10,500  
20  $\mu\text{m}$  and planarized by CMP.

The air gaps 126 may be formed in whole inter-metal dielectric layers, or in parts of the whole inter-metal dielectric layers. In the former, the air gaps 126 can be formed by one etching process (as shown in FIG. 2C), or  
25 formed by two or more etching process and separated by light transmitting insulating layers 128a, 128b and 128c without filling the air gaps 126 (as shown in FIG. 3). In the latter, after covering the light transmitting insulating layer 128 on the stacked inter-metal dielectric layer 122,  
30 the following interconnection process for forming another

inter-metal dielectric layer 122 is then performed, as shown in FIG. 4.

The optical guard rings used to prevent cross-talk between adjacent pixels in the present invention have a smaller index of refraction,  $n=1$ , such as air or other materials with  $n=1$ . When incident light is transmitted to the solid image sensor with air gaps as optical guard rings, the incident light may be completely reflected between the air gaps and the stacked inter-metal dielectric layer with a total reflection angle of  $45^\circ$ .

FIG. 5 shows the relationships between the cross-talk and the incident angle of incident light occurring in the traditional image sensor without optical guard rings in the stacked inter-metal dielectric layer and the image sensor of the present invention with air gaps formed in the inter-metal dielectric layers as the optical guard rings. Cross talk is defined as the signal of metal-light-shield pixel (which corresponds to the sensor areas 102b shielded with metal M4) divided by non-shield pixel (which corresponds to the sensor area 102a).

While there is no optical guard rings formed in the inter-metal dielectric layers IMD1, IMD2 and IMD3 as shown in FIG. 6, the relationship between the cross-talk and the incident angle of incident light is shown as line A in FIG. 5. While the air gaps 226B are formed in the inter-metal dielectric layers IMD2 and IMD3 as shown in FIG. 6, the relationship between the cross-talk and the incident angle of incident light is shown as line B in FIG. 5. While the air gaps 226C are formed in the inter-metal dielectric layers IMD1 and IMD2 as shown in FIG. 6, the relationship

between the cross-talk and the incident angle of incident light is shown as line C in FIG. 5.

As can be seen in FIG. 5, the cross-talk problem is serious when incident angle becomes larger, especially -30° ~ -40° and 30° ~ 40°, in the traditional image sensor. On the contrary, the cross-talk problem can be almost omitted in the image sensor with air gaps as optical guard rings.

The foregoing description of the preferred embodiments of this invention has been presented for purposes of illustration and description. Obvious modifications or variations are possible in light of the above teaching. The embodiments were chosen and described to provide the best illustration of the principles of this invention and its practical application to thereby enable those skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the present invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.